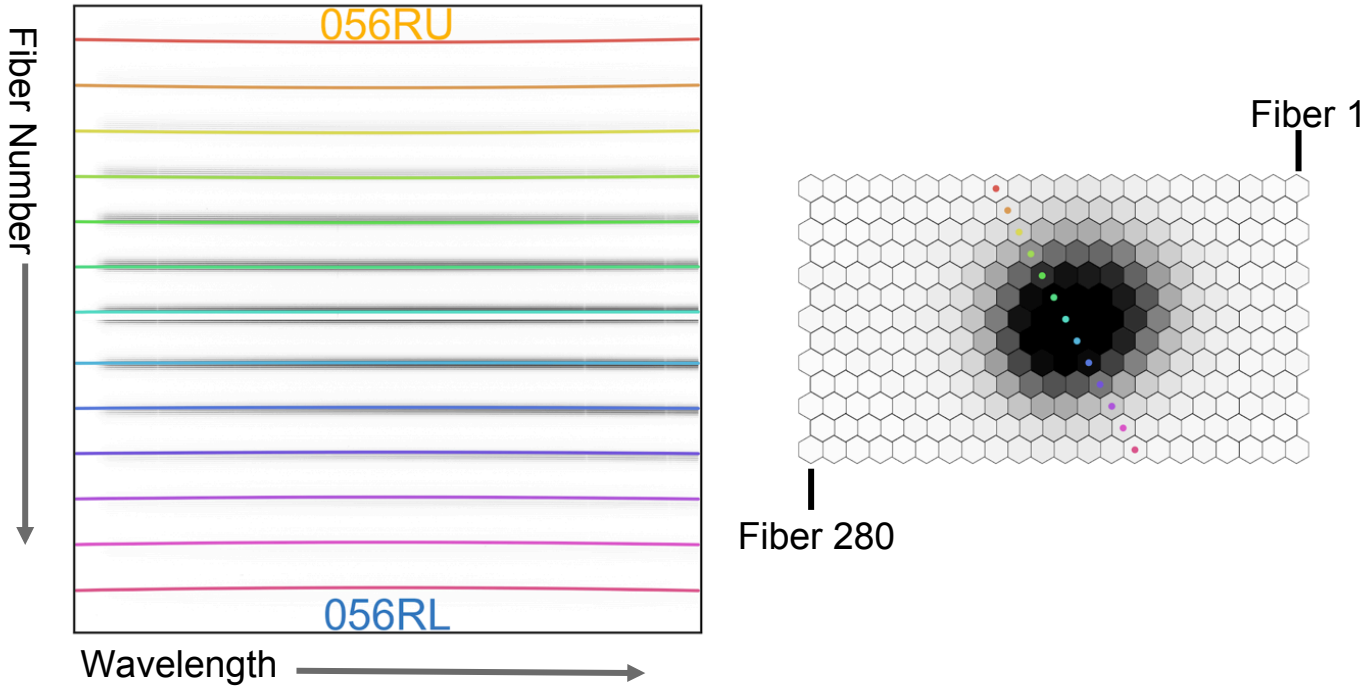
LRS2 REDUCTIONS

Greg Zeimann
HET Data Scientist

Automatic Reductions

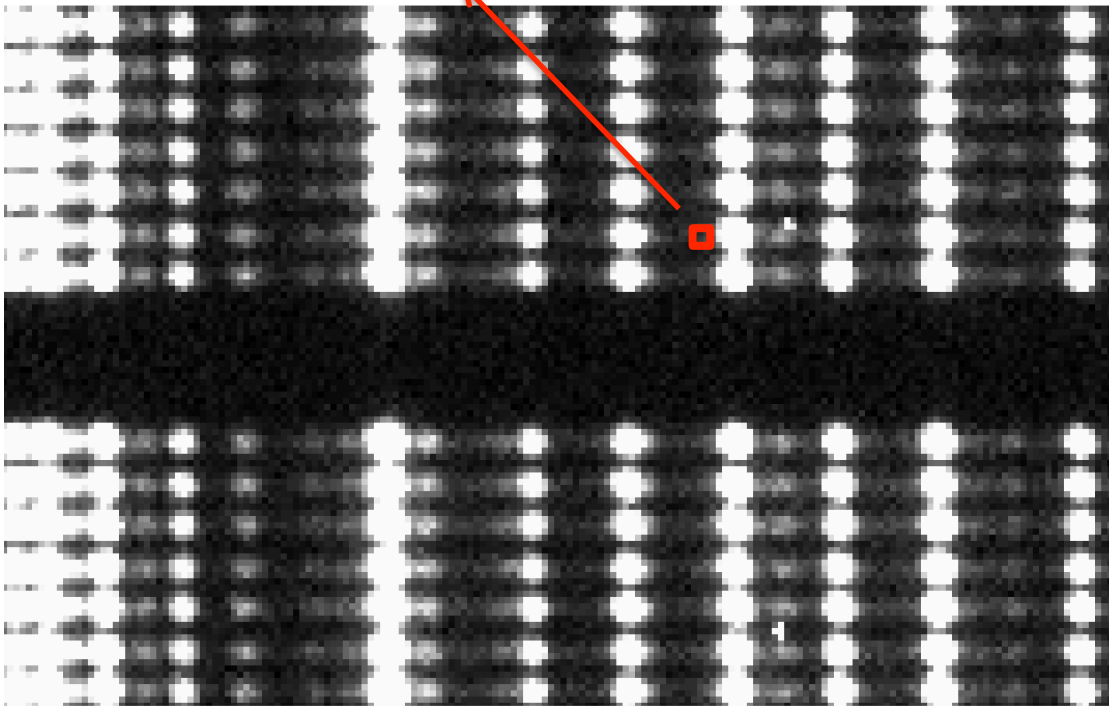
- Goal: Science-grade data reduction products
- Run from January 1st 2019 and on
- Older reductions can be run by the user
  - https://github.com/grzeimann/Panacea#running-the-reductions-yourself
  - Or email grzeimann@gmail.com for help
- TACC resources: Wrangler and Stampede2
- Pipeline reference in preparation (Zeimann et al. 2019)

Mapping Raw Data to Sky



Panacea: a python based reduction code

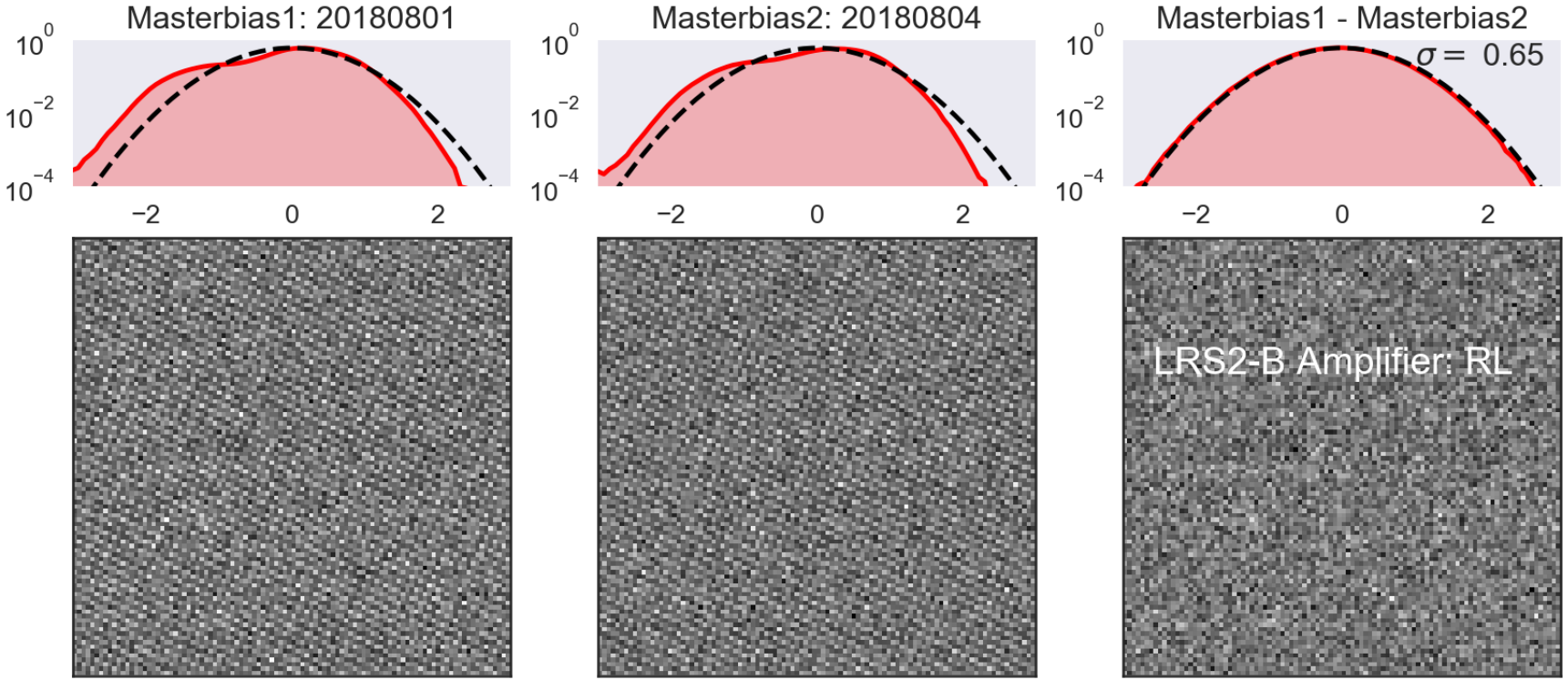
$$P_{ij} = B + B_{ij} + D_{ij} + Q_{ij} \times (S_{ij} + Sky_{ij} + Sci_{ij}) + \delta_{ij}$$



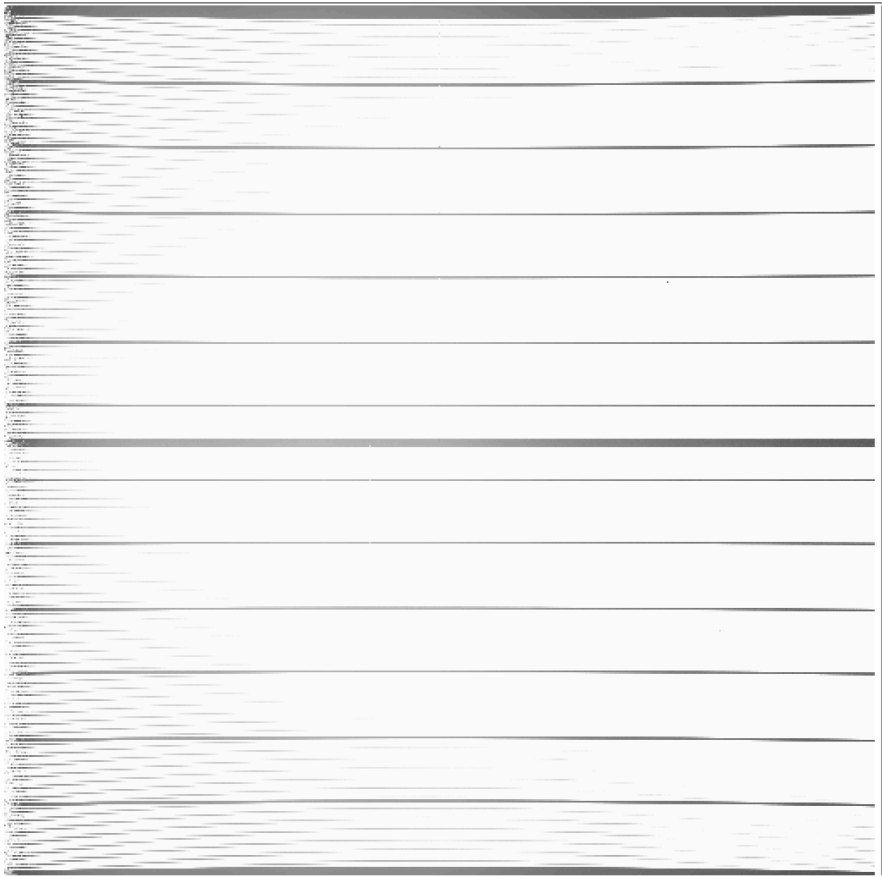
B: Overscan
B_{ij}: Bias Structure
D_{ij}: Dark
Q_{ij}: Pixel to Pixel Variation
S_{ij}: Scatter Light
Sky_{ij}: $\Sigma_{fw} Sky_f(w) \times PSF_f(w)$
Sci_{ij}: $\Sigma_{fw} Sci_f(w) \times PSF_f(w)$

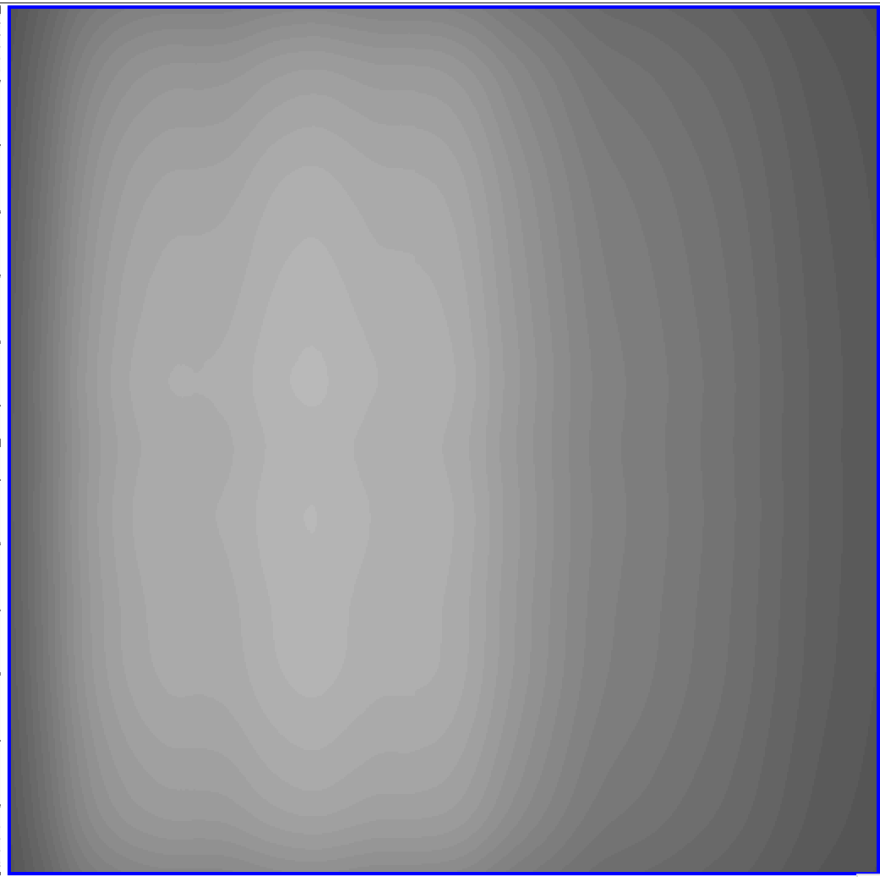
Bias Subtraction: Master Bias Pattern (Evolves Slowly)

Initial Noise (Read Noise + Pattern Noise) = ~3.0 e-

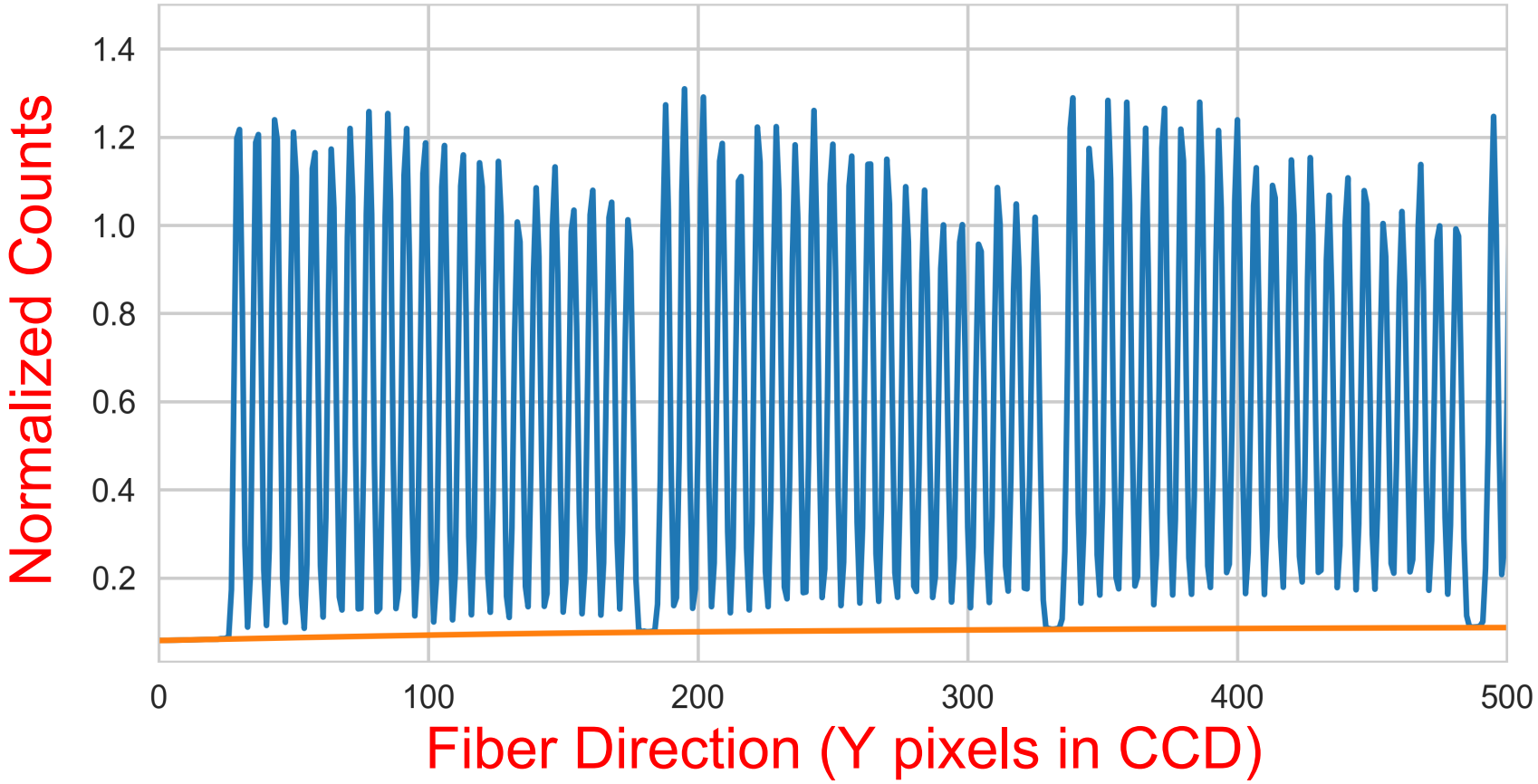


Scattered Light: powerlaw

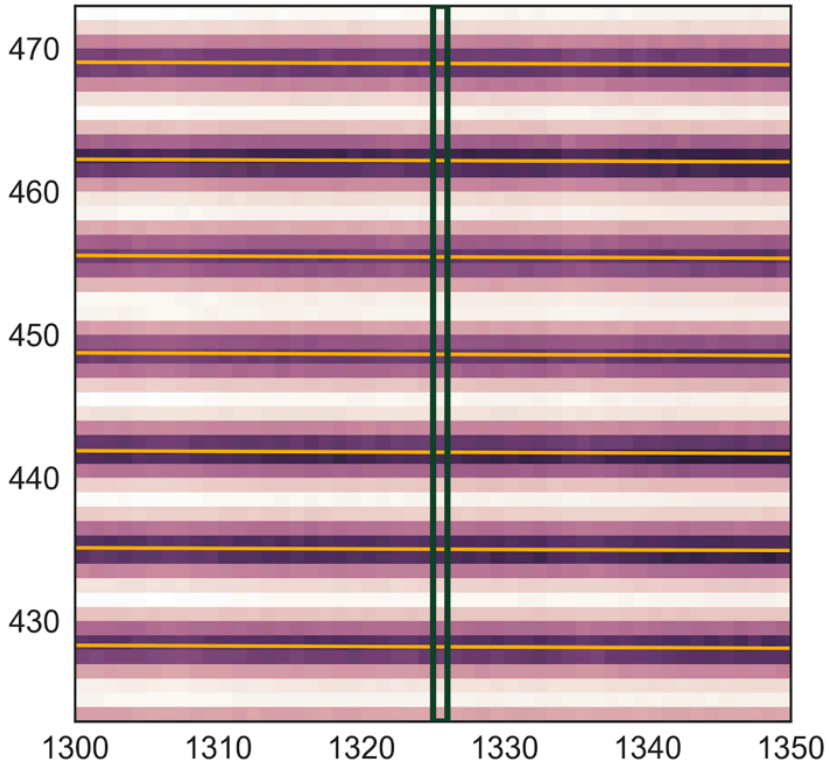


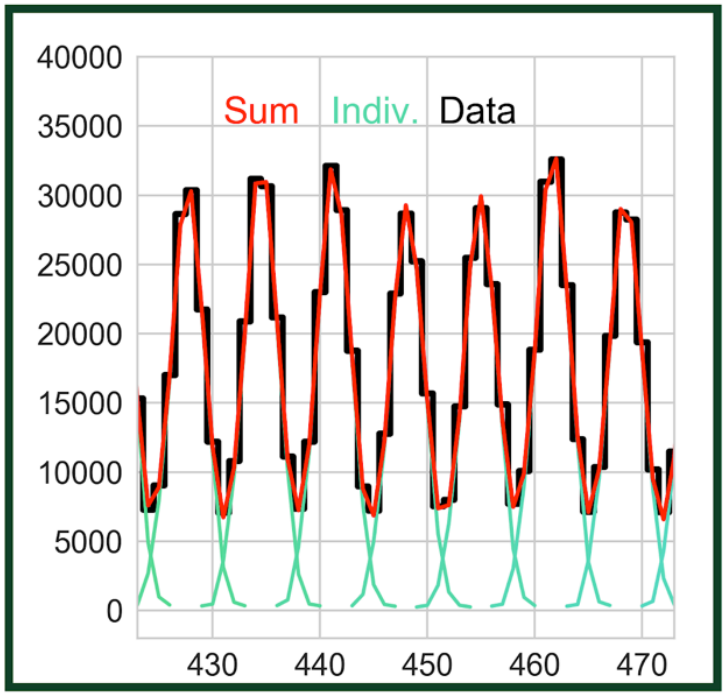


Scattered Light: powerlaw

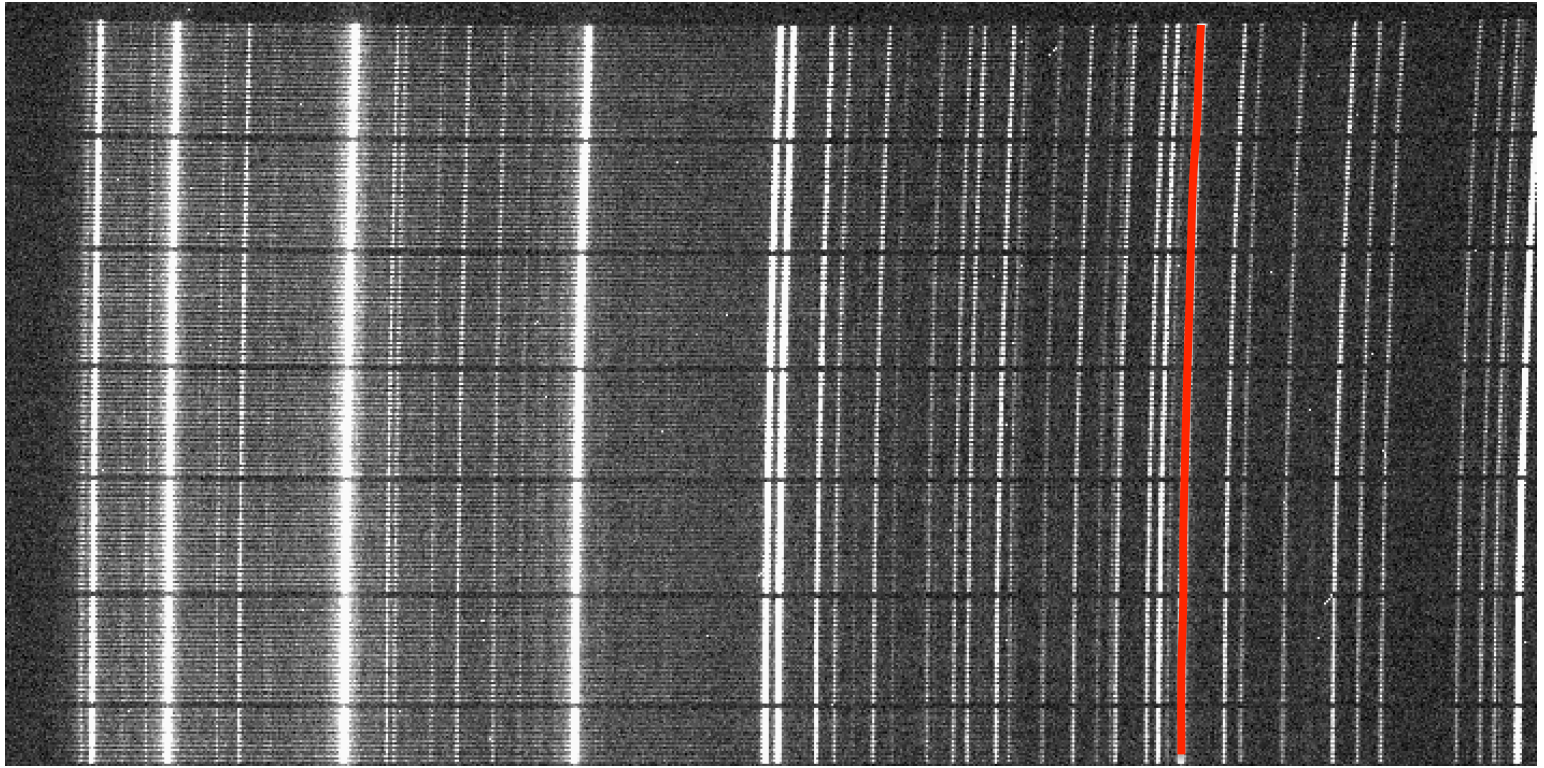


Trace: peak estimation with quadratic

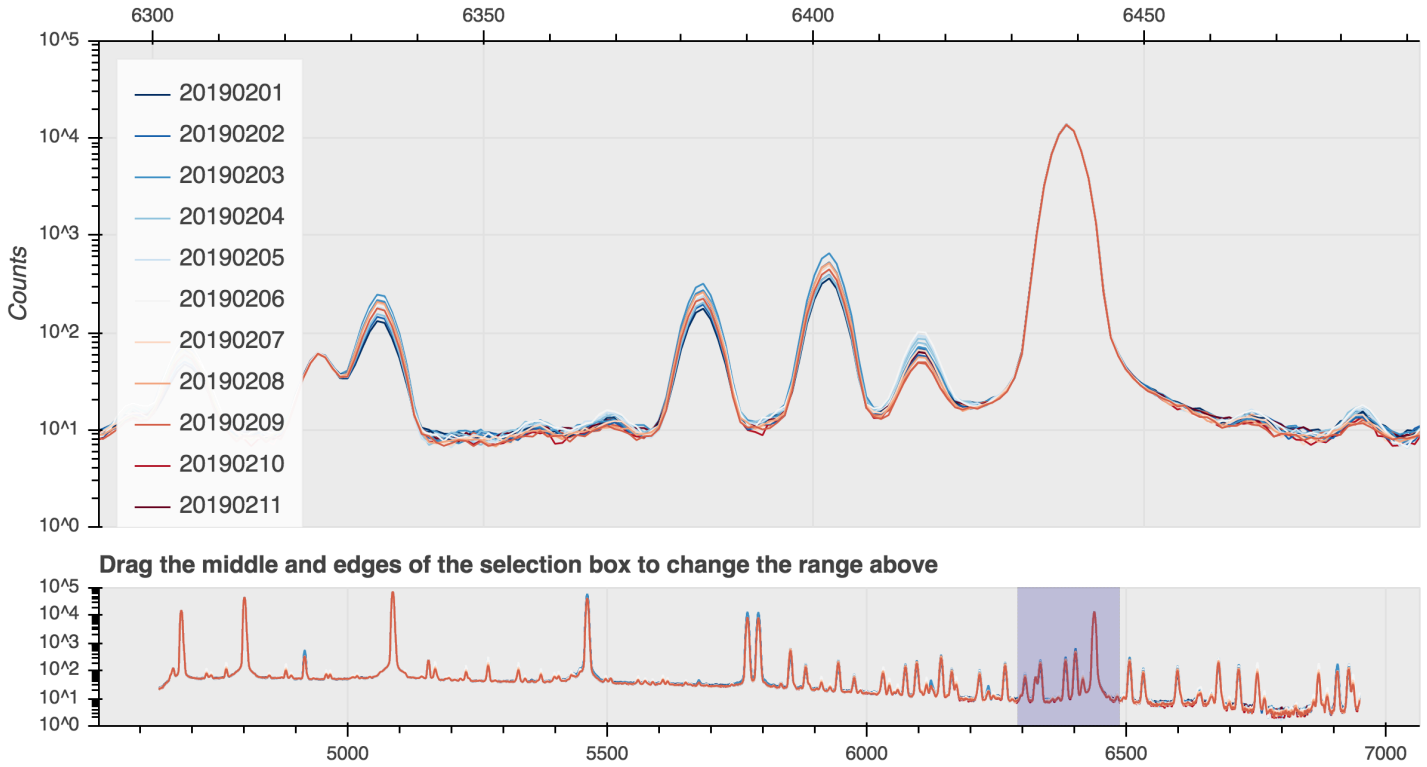




Wavelength Solution: Hg, Cd, Ne, FeAr



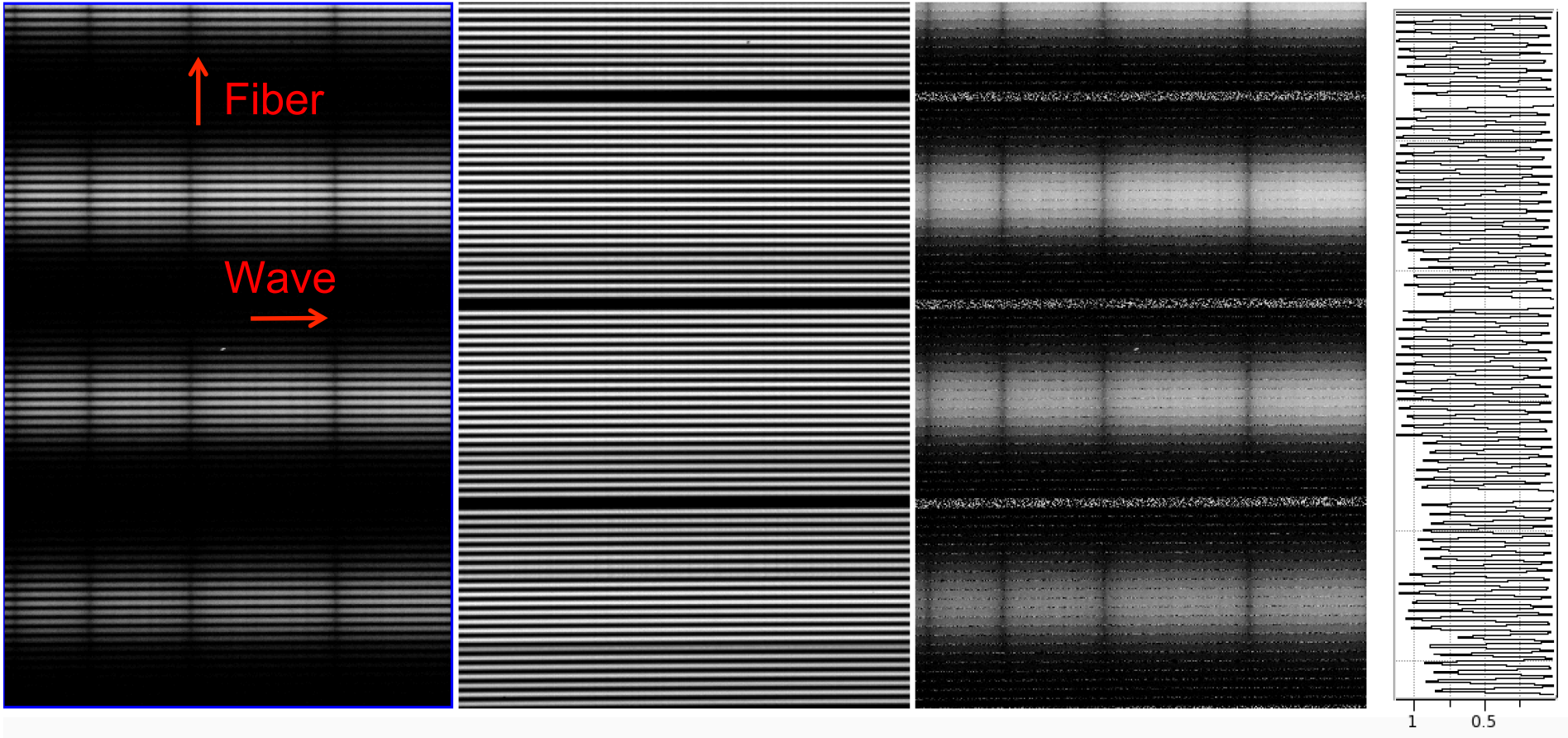
Wavelength Solution: 3rd order Poly



Air wavelengths

No barycentric correction

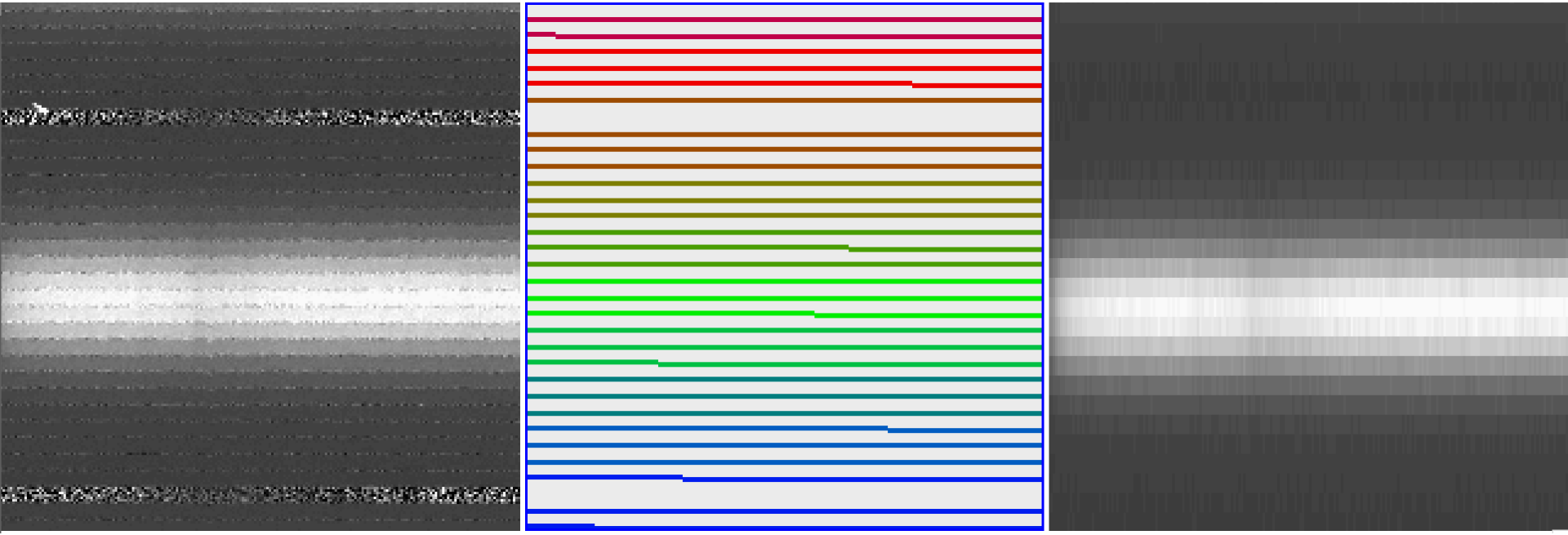
Flat Fielding



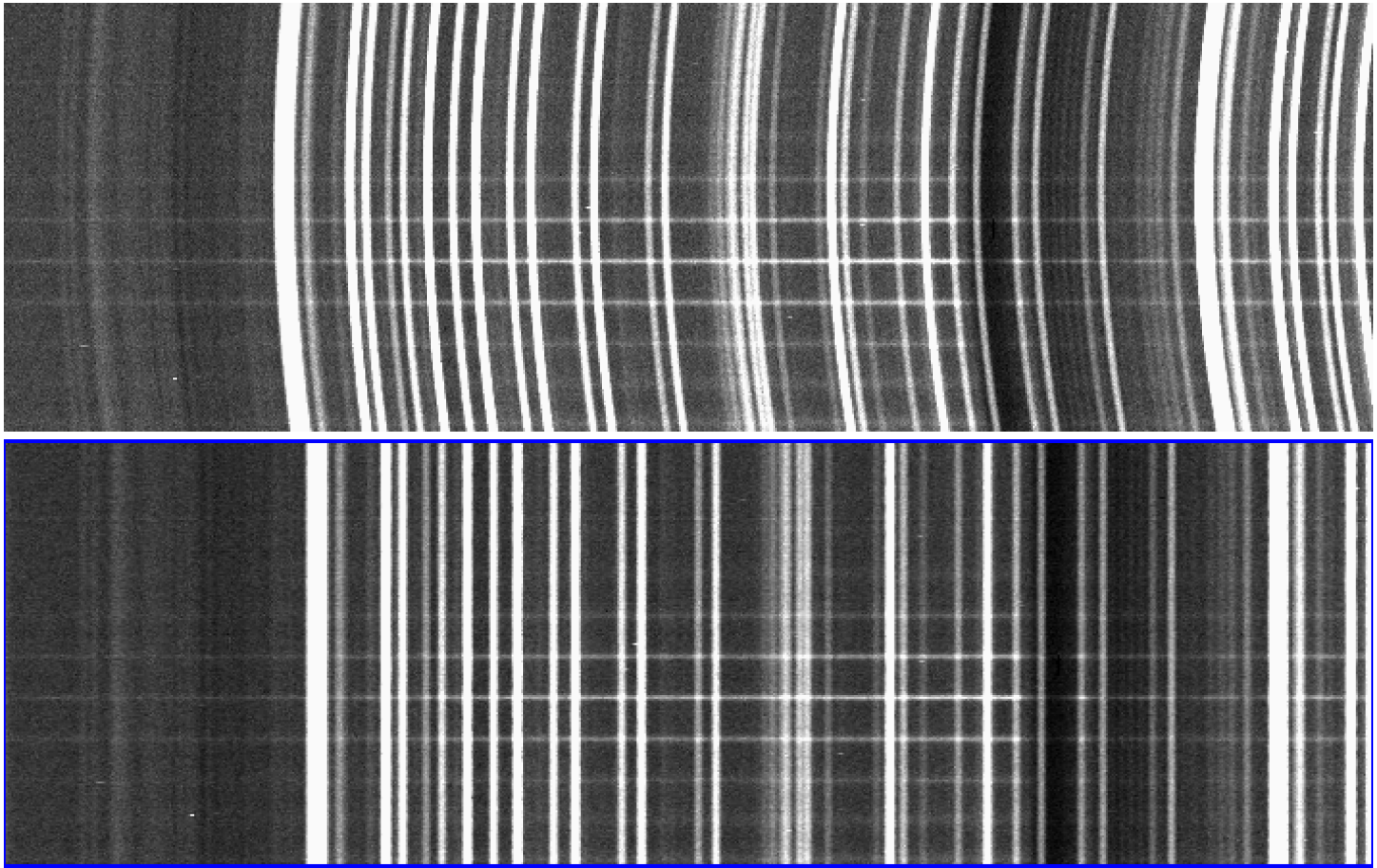
Fiber Extraction

Row x Column → Fiber x Column

2064 x 2064 → 280 x 2064



Linear Rectification



Sky Subtraction

Step 1: Median of the bottom 5% fibers

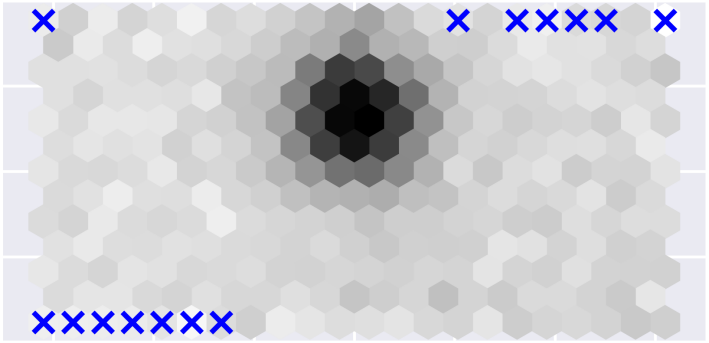
Step 2: Find scaling to sky lines for each fiber

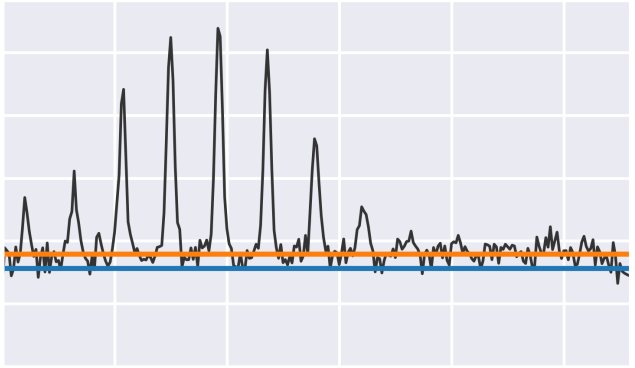
Step 3: Subtract

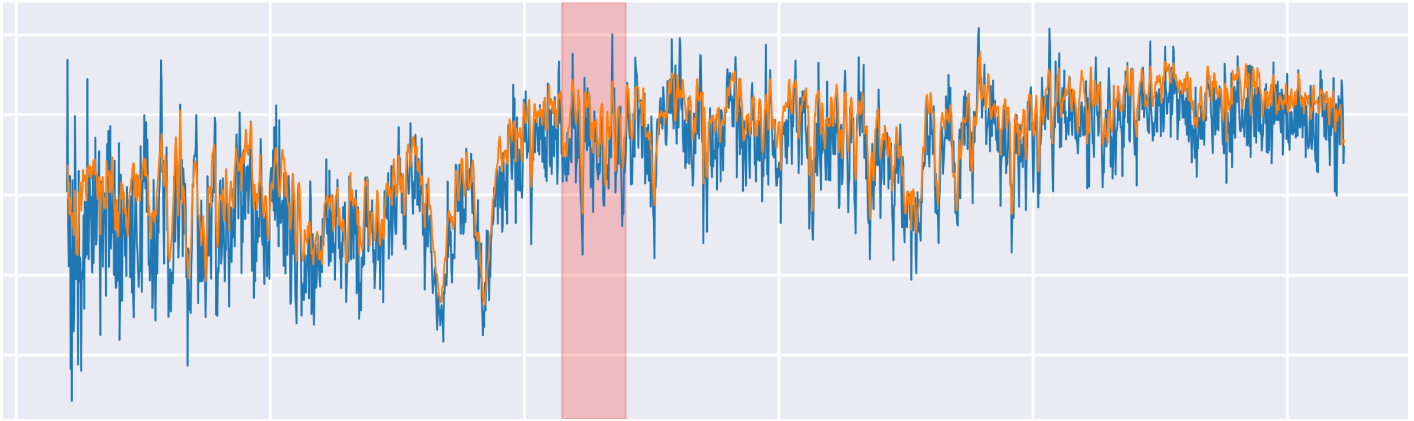
Step 4: Keeping the same scaling per fiber fixed, subtract residual sky up to 0.5σ

Caveat: Does not deal with differential spectral dispersion of each fiber

Sky Subtraction

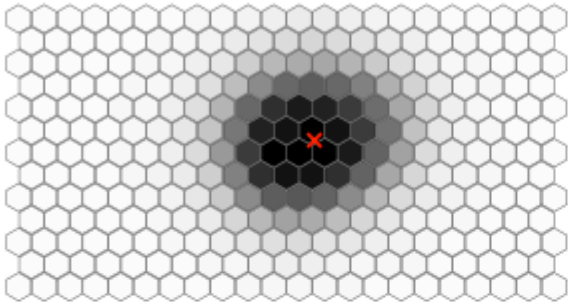






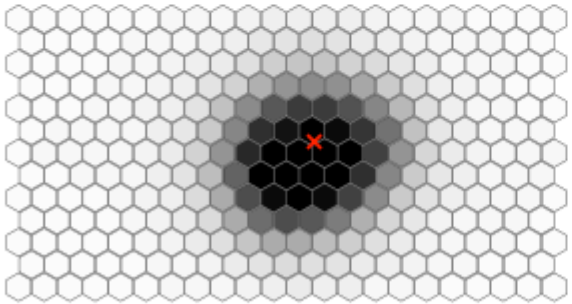
Atmospheric Differential Refraction

ORANGE CHANNEL
BLUE λ

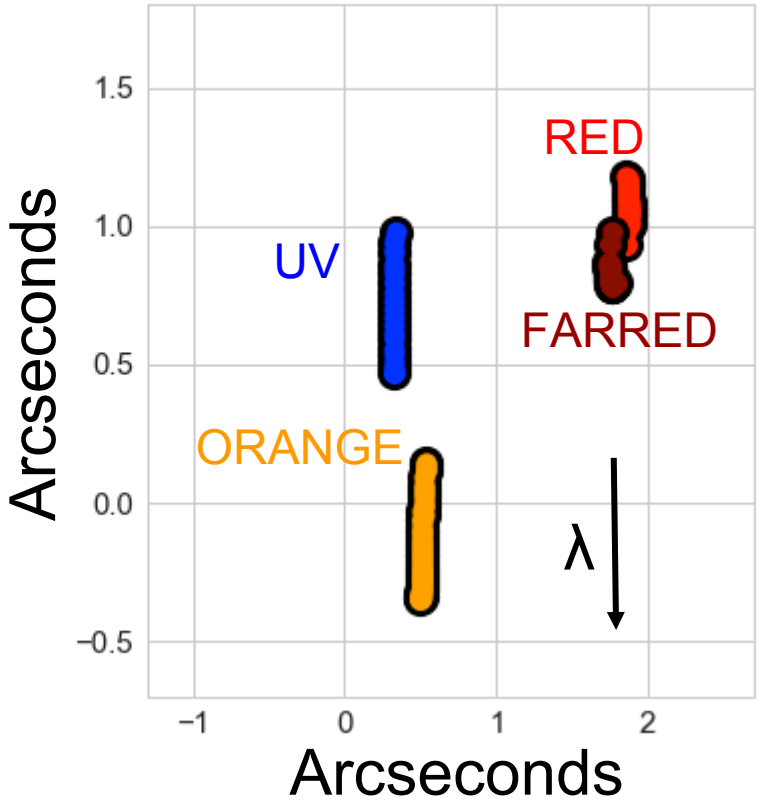


4700 Å

ORANGE CHANNEL
RED λ



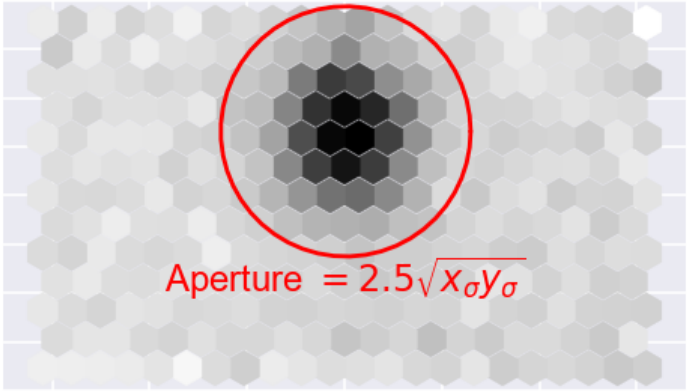
6700 Å

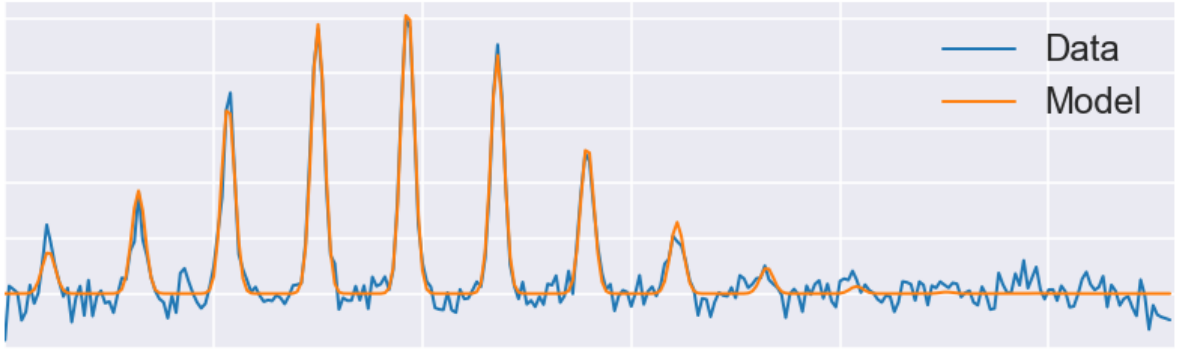


Object Extraction (Emission and Cont.)

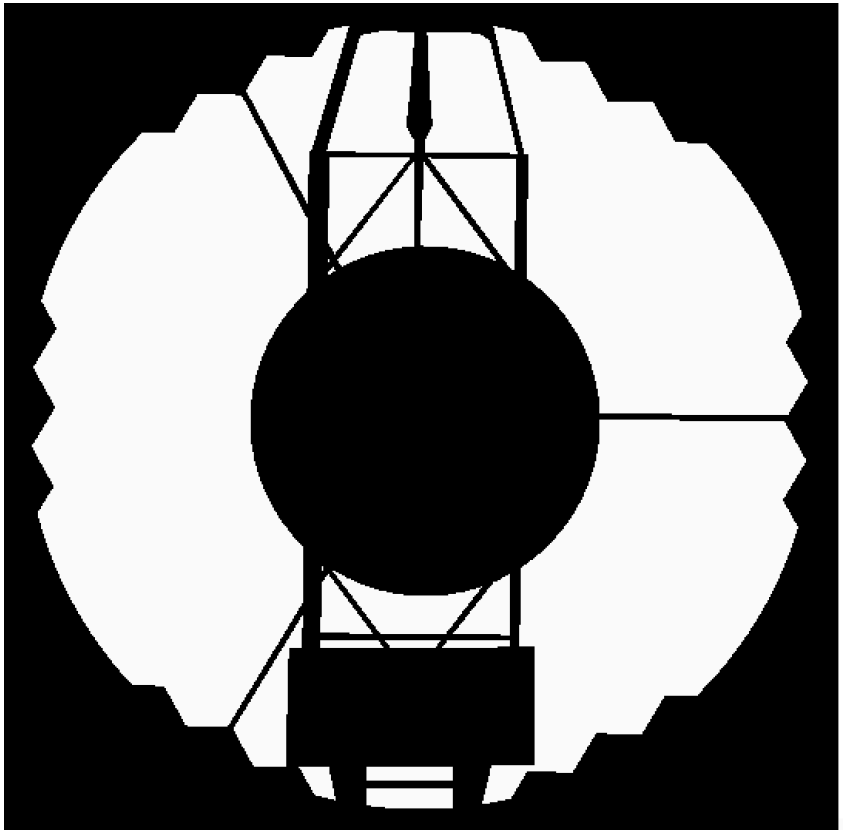
① Aggressively mask sky lines (|λ – skyline| < 6Å)
② Aggressively mask cosmics
③ Convolve spatially (r = 0.75")
④ Convolve spectrally (r = 1.5 pixels)
⑤ Locate maximum S/N in convolved cube
⑥ Expand in wavelength direction if S/N increases
⑦ If S/N > 5, fit bivariate Gaussian to maximum S/N image
⑧ Use bivariate Gaussian for weighting in optimal extraction

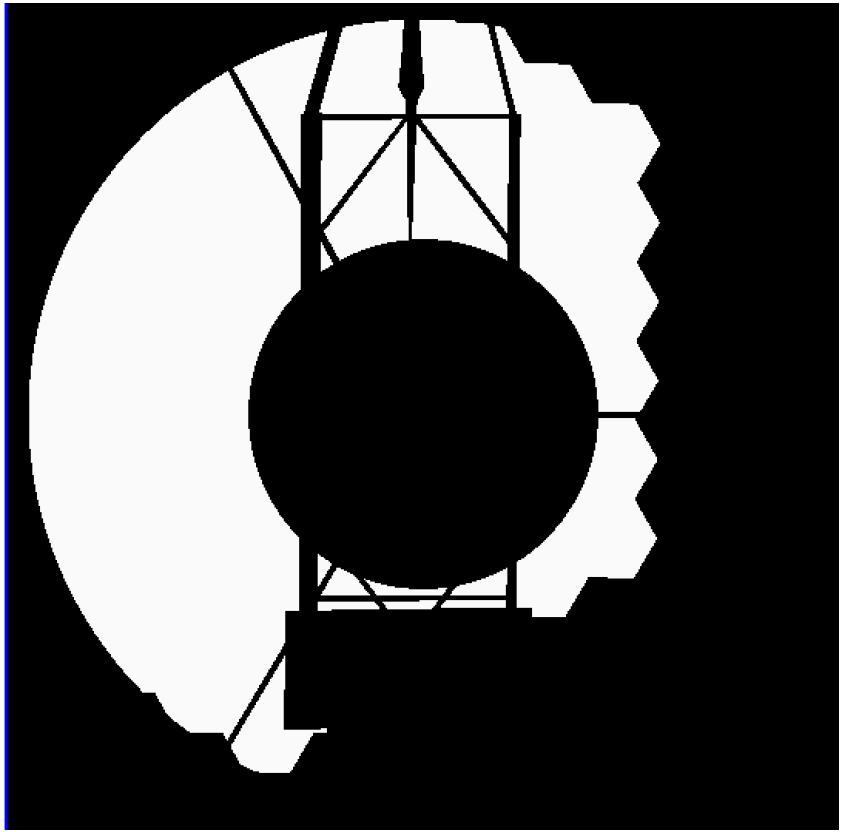
Object Extraction (Emission and Cont.)





Flux Calibration (HET is complicated)





Flux Calibration (HET is complicated)

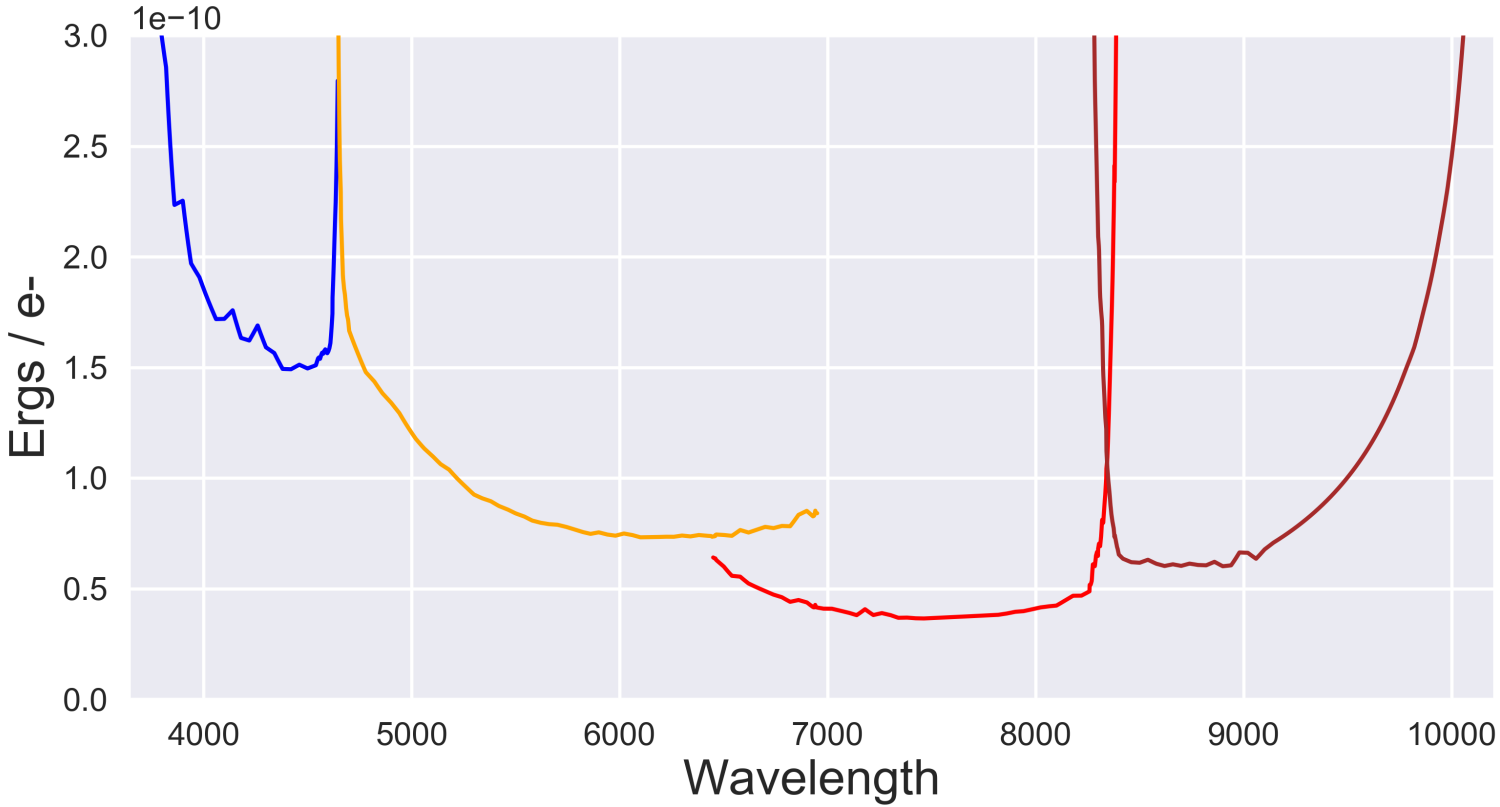
① Raw data: ADU per pixel
② Initial extracted fibers: e- / Å
③ Mirror illumination and exposure time: e- / s / cm^2 / Å
④ Single response function: ergs / s / cm^2 / Å
    ① All fibers and spectra

Atmospheric extinction not included

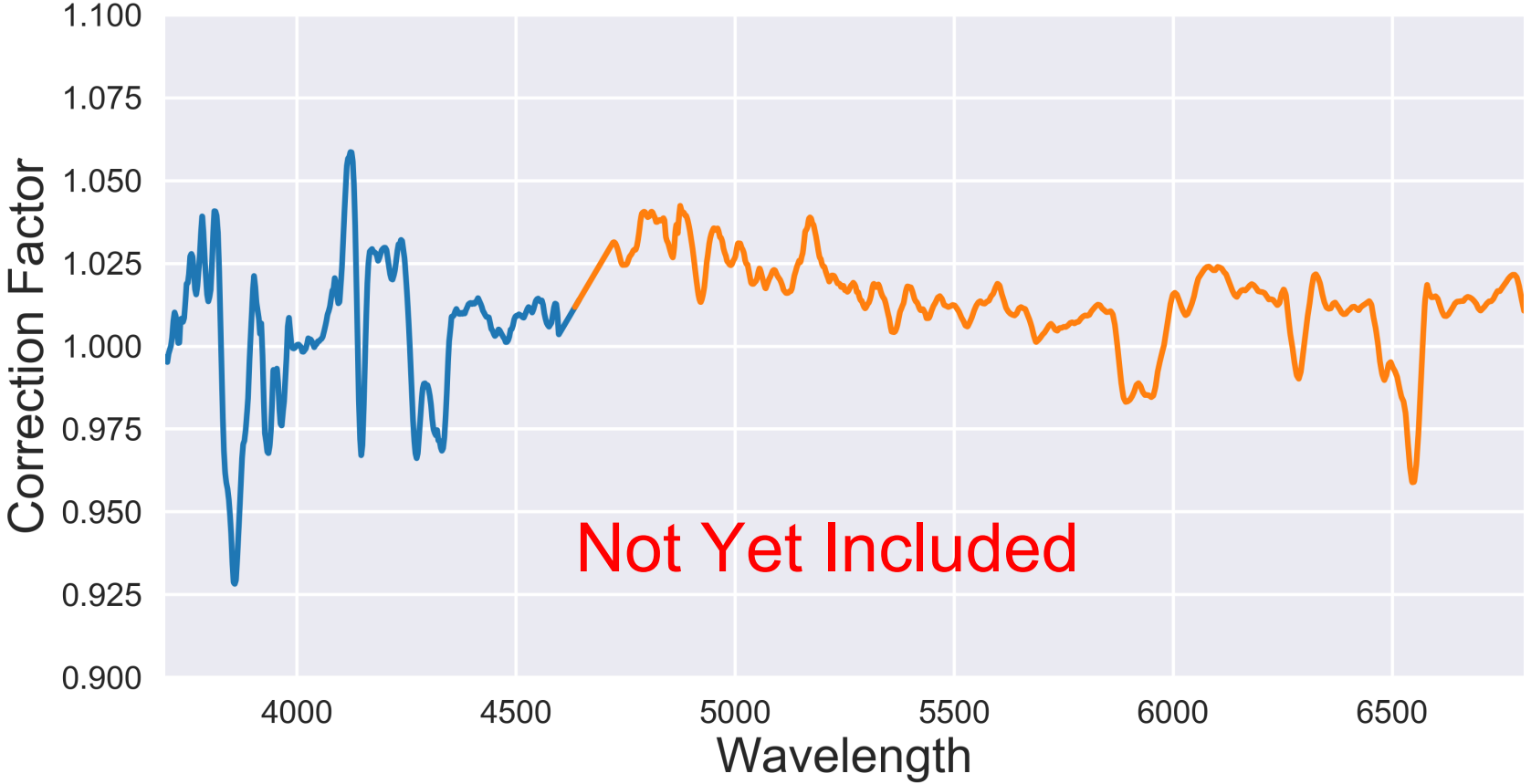
No telluric correction

Instrument assumed stable

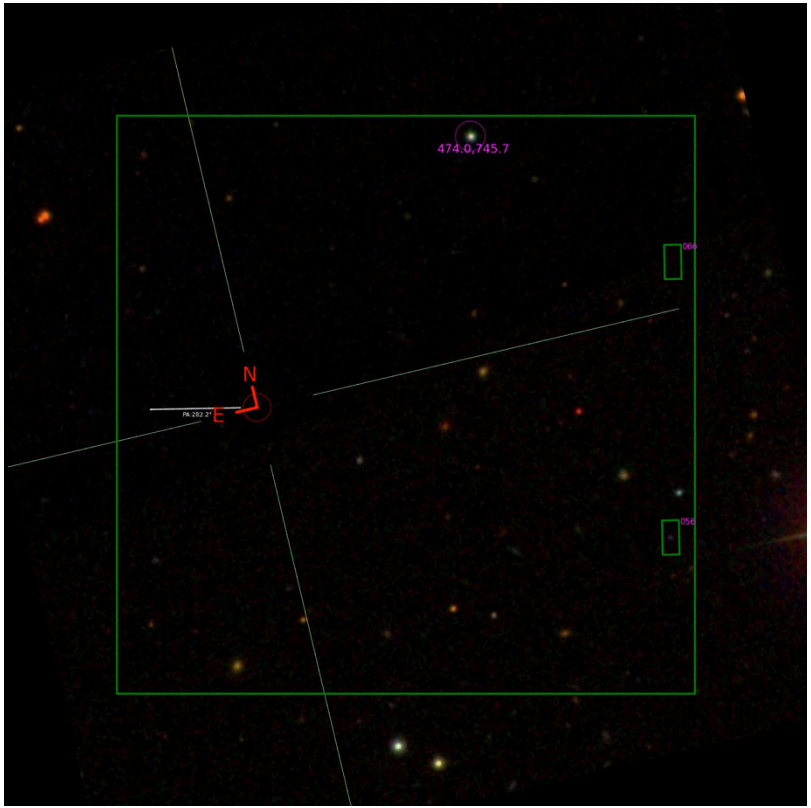
Flux Calibration (One single response)

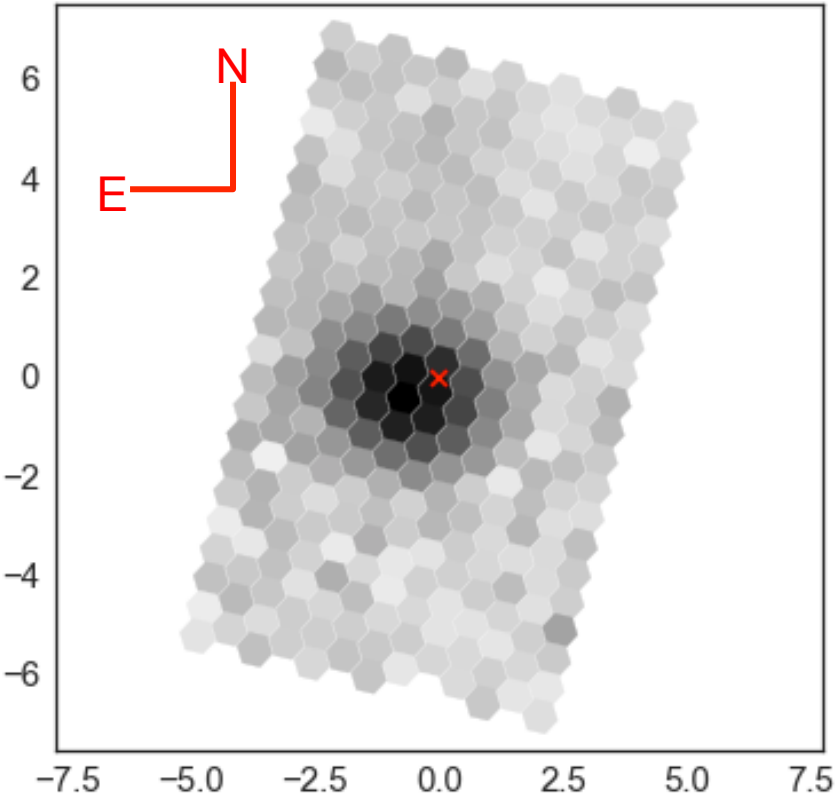


Flux Calibration (Flat fielding correction)



Astrometry





Documentation: https://github.com/grzeimann/Panacea

GitHub, Inc. [US] | https://github.com/grzeimann/Panacea

Panacea v1.0 (Automatic LRS2 Pipeline)

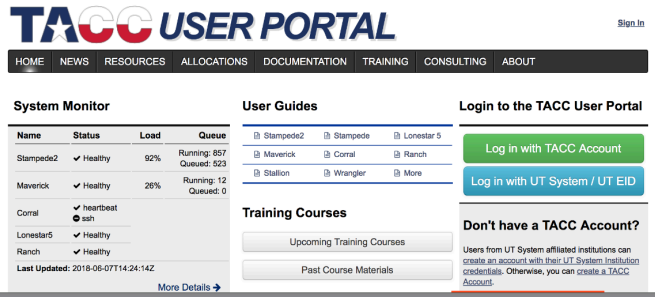
This package is the reduction pipeline for LRS2 observations at the Hobby Eberly Telescope. Every morning the pipeline reduces data taken the previous night. Below we discuss the algorithms and products of Panacea, how to access your data reductions, and how to run the pipeline yourself with varying options. All of the data reduction products live on the Texas Advanced Computing Center (TACC). We start with the instructions to log on to TACC, and where you reductions are placed.

Working on TACC

The reductions are designed to be run on TACC where a copy of the raw data lives. We will describe how to get started on TACC, where the automatic reduction products live, how to run the code yourself, and the products that are produced.

Signing up for an account

https://portal.tacc.utexas.edu/



How to retrieve your reductions

Description of algorithms

Description of products

Frequently asked questions

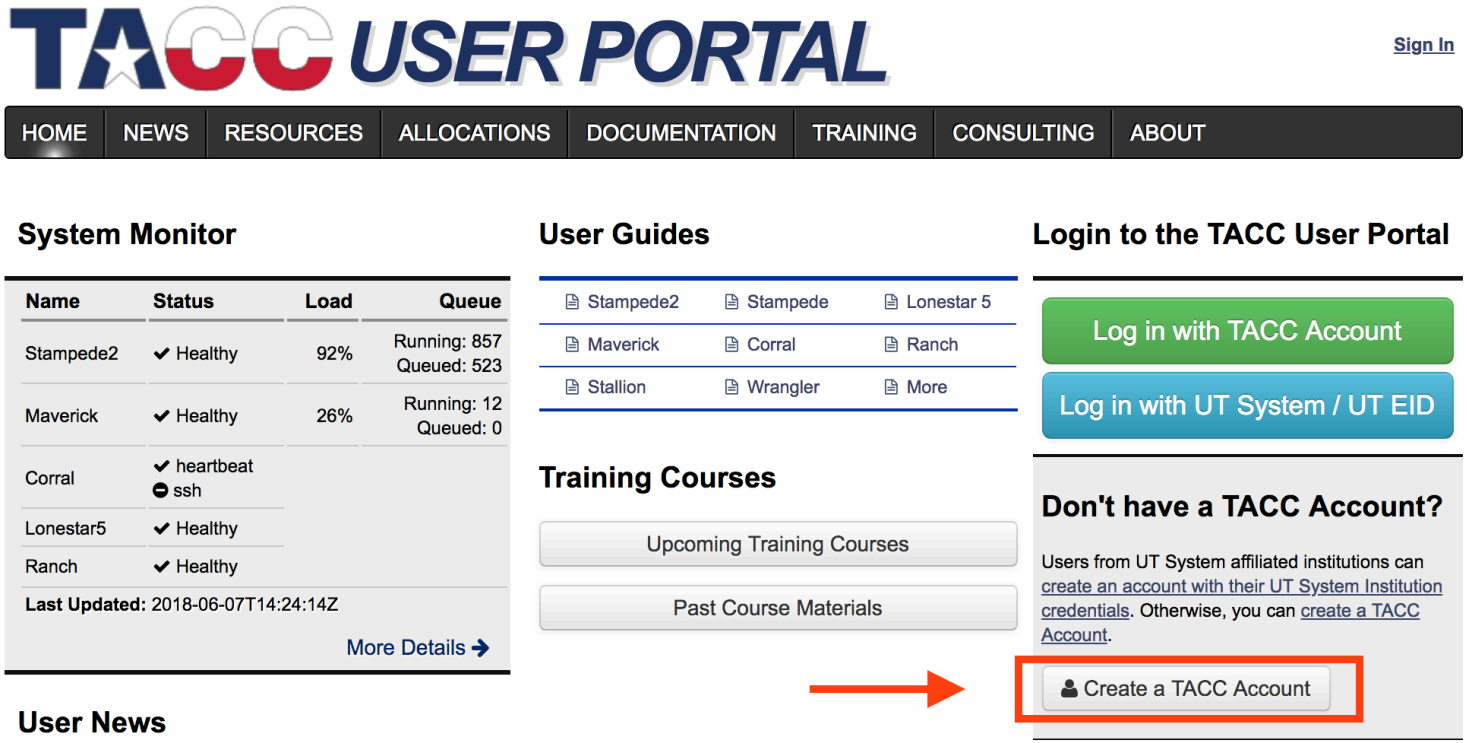
LRS2 Pipeline (Started Jan 1st)

Automated email example:

```
Your program got new data:

Object          |File            |Setup          |Accept               |RA_notes
-----------------------------------------------
OBJNAME_056_W    |lrs20000024_01 |LRS2-B          |accepted             |
OBJNAME_066_W    |lrs20000025_01 |LRS2-R          |accepted             |

Data reductions complete.

Your reductions can be found on TACC: /work/03946/hetdex/maverick/LRS2/HET19-1-999

Description of the reduced products, the pipeline, and how to access the data are here: https://github.com/grzeimann/Panacea

Please contact Greg Zeimann (grzeimann@gmail.com) if you have any questions about your reductions.
```

How to get your reductions

Step 1: Get TACC account; email shetrone@astro.as.utexas.edu



How to get your reductions

Step 2: Copy your Program-ID to your convenient location

scp –r USER@wrangler.tacc.utexas.edu:/work/03946/hetdex/maverick/LRS2/PROGRAM-ID .

This will return four files for each exposure and each channel (e.g., Orange)

multi_DATE_OBSID_expXX_SIDE.fits

spectrum_DATE_OBSID_expXX_SIDE.fits

DATE_OBSID_expXX_obs_SIDE_cube.fits

DATE_OBSID_expXX_sky_SIDE_cube.fits

DATE_OBSID_expXX_skysub_SIDE_cube.fits

Reduction Folder Structure (on TACC)

Base = /work/03946/hetdex/maverick

LRS2/CALS

Wavelength, trace, fiber flat image, arc spectra, master bias, ect.

LRS2/STANDARDS

Standard stars for post flux calibration or telluric calibration

LRS2/ORPHANS

Science observations without PROGRAM-ID's

LRS2/PROGRAM-ID

Science observations belonging to PROGRAM-ID

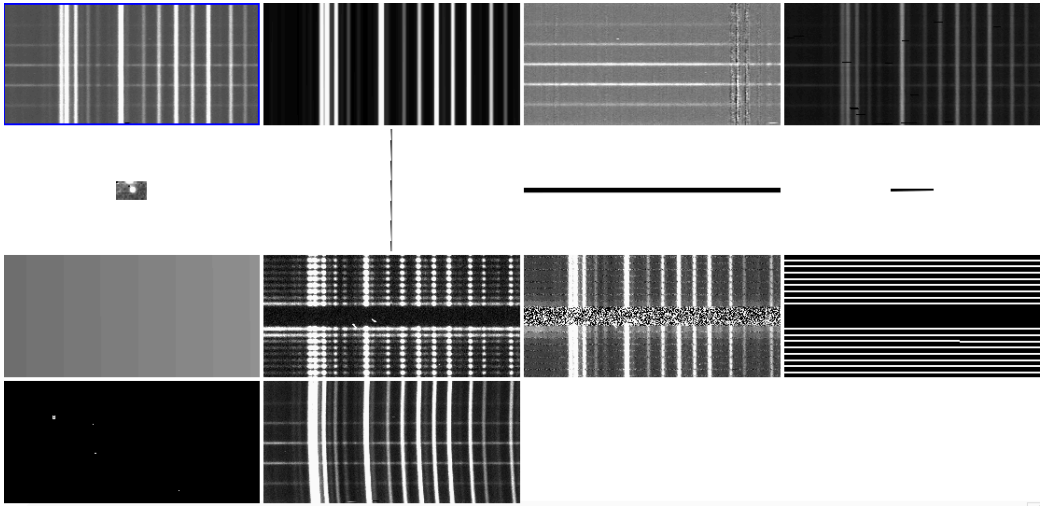
Data Reduction Products:
spectrum_DATE_OBSID_expXX_SIDE.fits

1) Wavelength
2) F_λ (ergs / s / cm^2 / A)
3) Sky_λ
4) e_F_λ
5) e_Sky_λ
6) Response

```
import matplotlib.pyplot
import glob
from astropy.io import fits
plt.figure(figsize=(10, 8))
fn = glob.glob('PROGRAM-ID/spectrum_DATE_OBSID_EXP_*.fits')
for f in fn:
    F = fits.open(f)
    plt.plot(F[0].data[0], F[0].data[1])
```

Data Reduction Products:
multi_DATE_OBSID_expXX_SIDE.fits

1. Rectified Spectra
2. Rectified Sky Model
3. Rectified Sky Subtracted Spectra
4. Rectified Error Frame
5. Collapsed image
6. Positions (IFU, Focal, Sky)
7. Extracted Spectra and Response
8. ADR
9. CCD Wavelength
10. Image
11. Flat Fielded image
12. Central Trace Pixels
13. Cosmics
14. Unrectified Spectra



Data Reduction Products:

DATE_OBSID_expXX_{kind}_SIDE_cube.fits

QFitsView